ILD
Muon System
/ Tail Catcher

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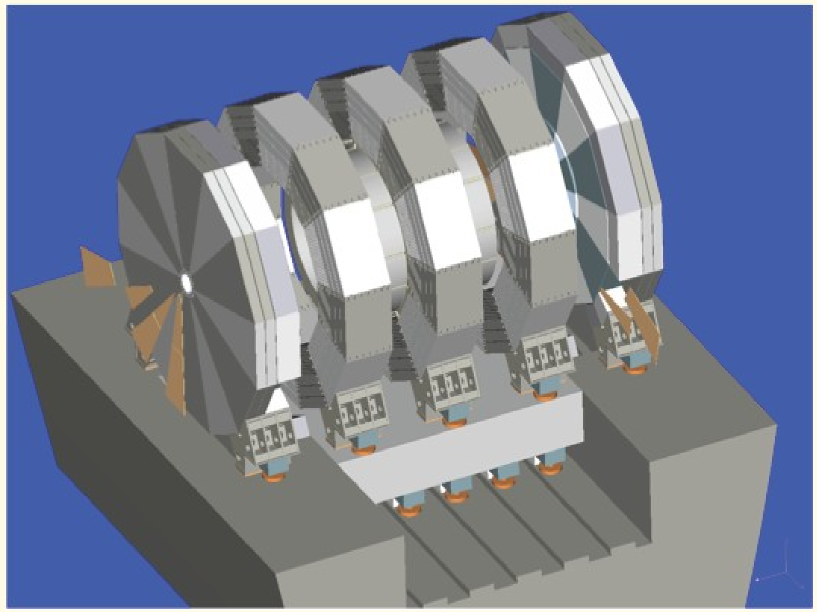
Muon System/Tail Catcher Structure

The tasks of the Muon System are:

- Identification of muons (tracking as part of PFA)
- Tail Catcher for HCAL (energy leakage)



Modules:	Barrel: 3	Endcap: 2
Rmin, Rmax, length [mm]	4450, 7760, 2800	300, 7760, 2560
No. of sens. layers	14	12
Scintillation strips:	total 125000	
thickness, width, length [mm]	10, 30, 2800	

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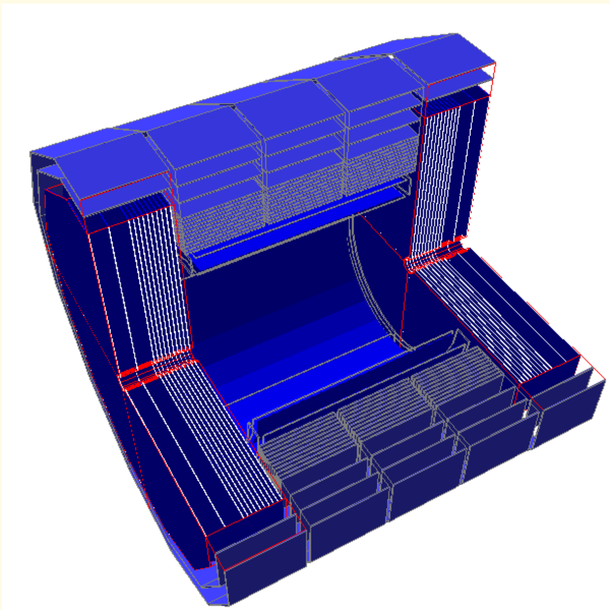
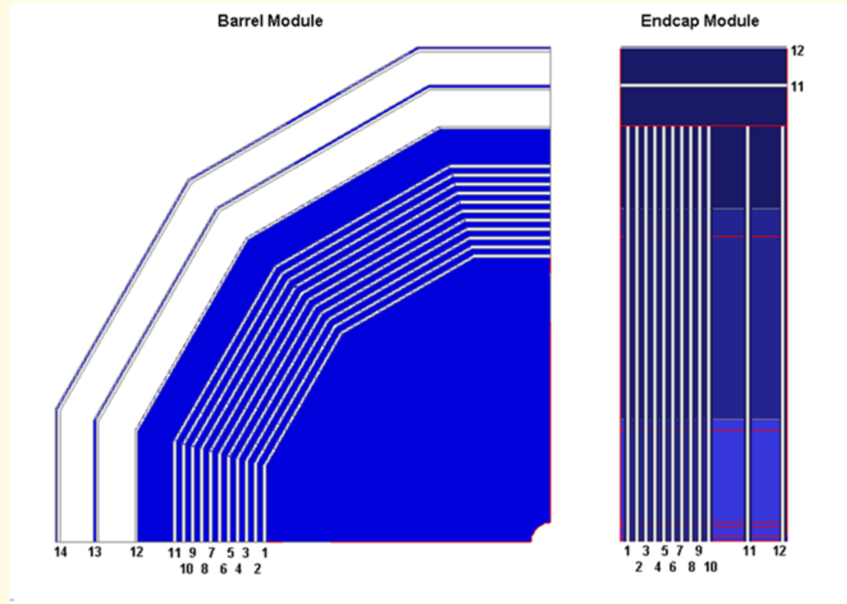




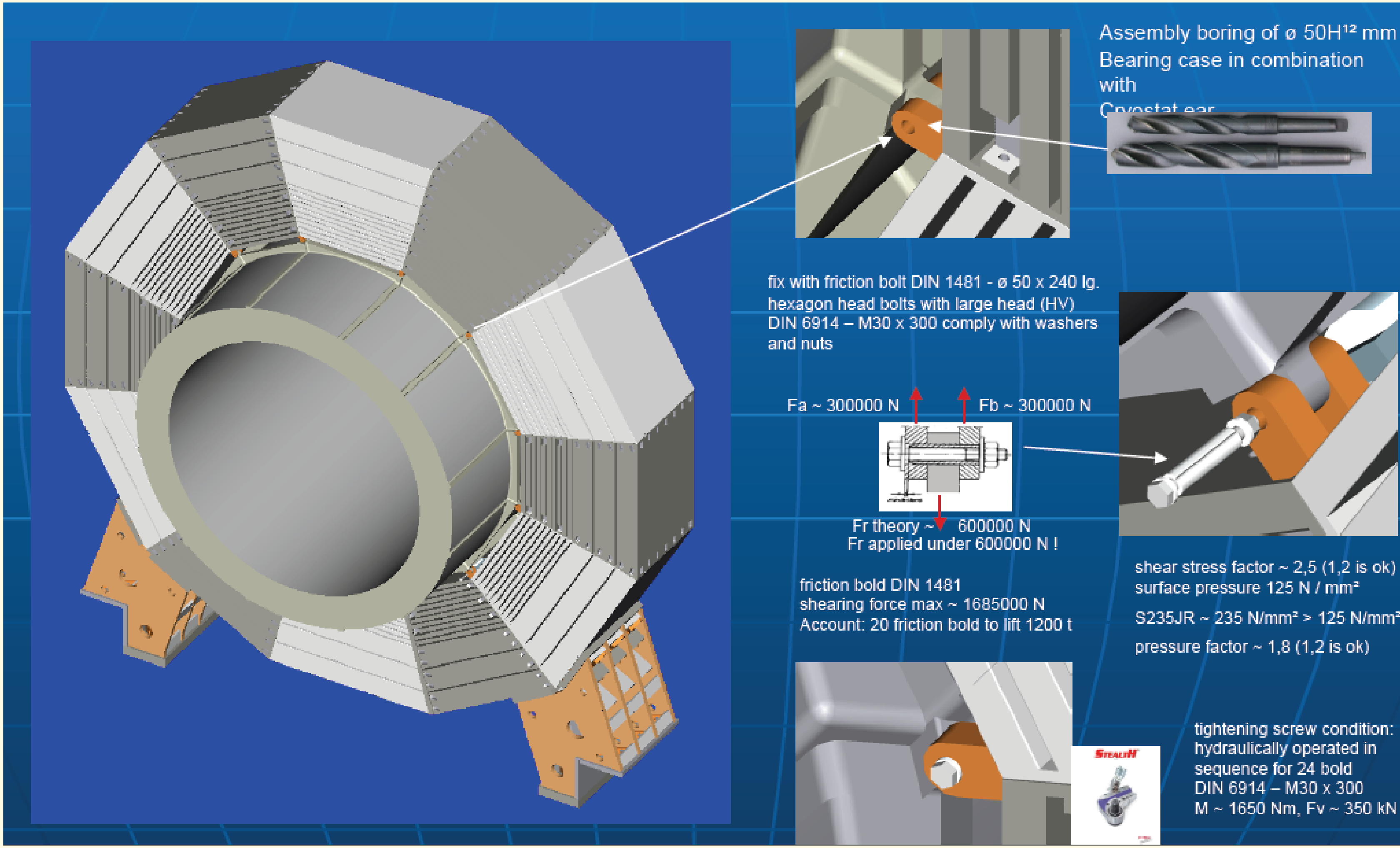
Yoke:

- Barrel Instrumentation: 40 + 10*(100+40) +3*(560 + 40) mm (14 Sens Layers)
- EndCup Instrumentation: 10*(100+40) +2*(560 + 40) mm (12 Sens Layers)

Cryostat (as option) :

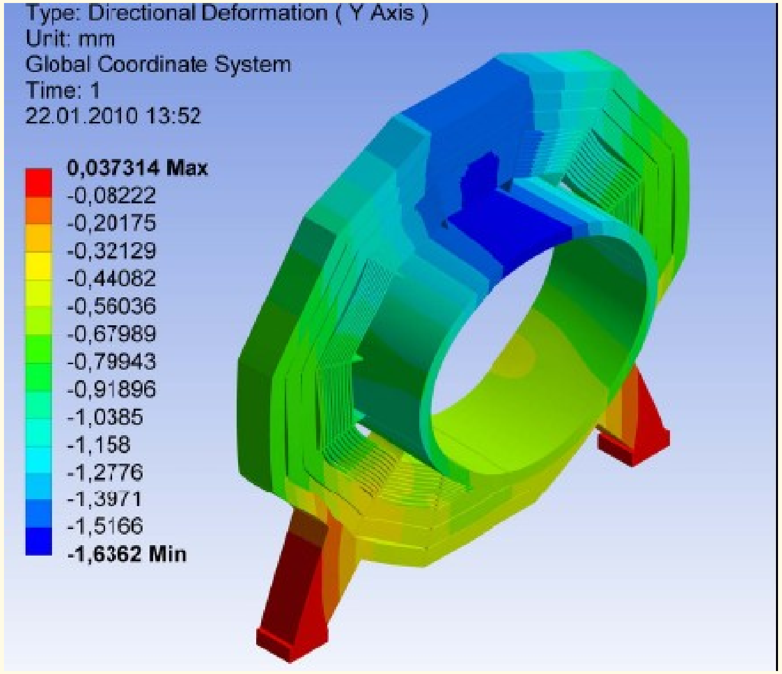
- Instrumentation: 2 Sens Layers

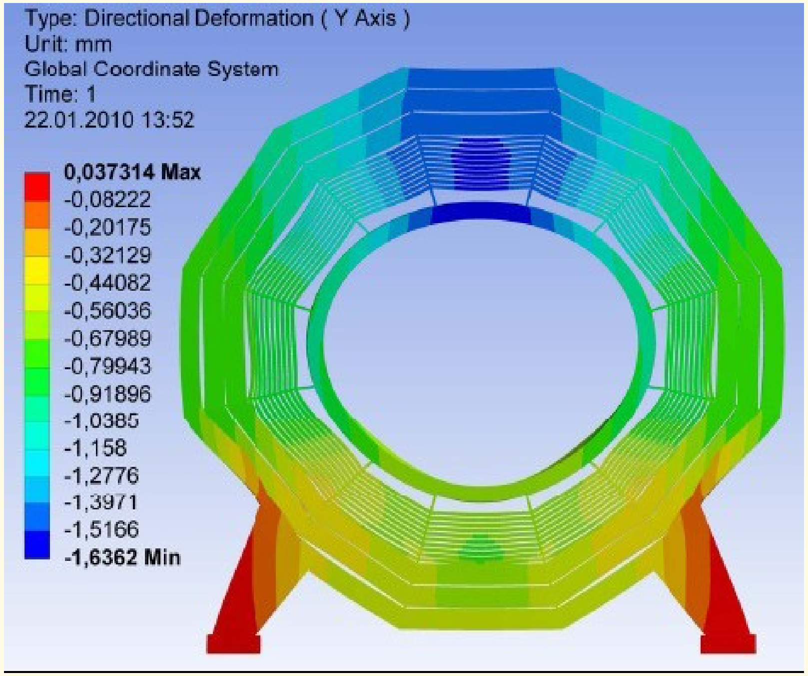
Mechanical Study of ILD Magnet and Muon System



R. Stromhagen

Mechanical Study of ILD Magnet and Muon System

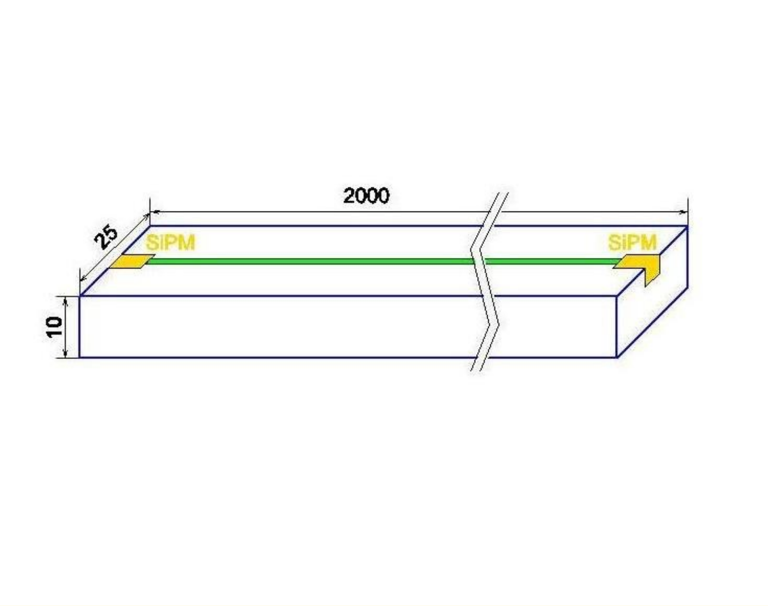




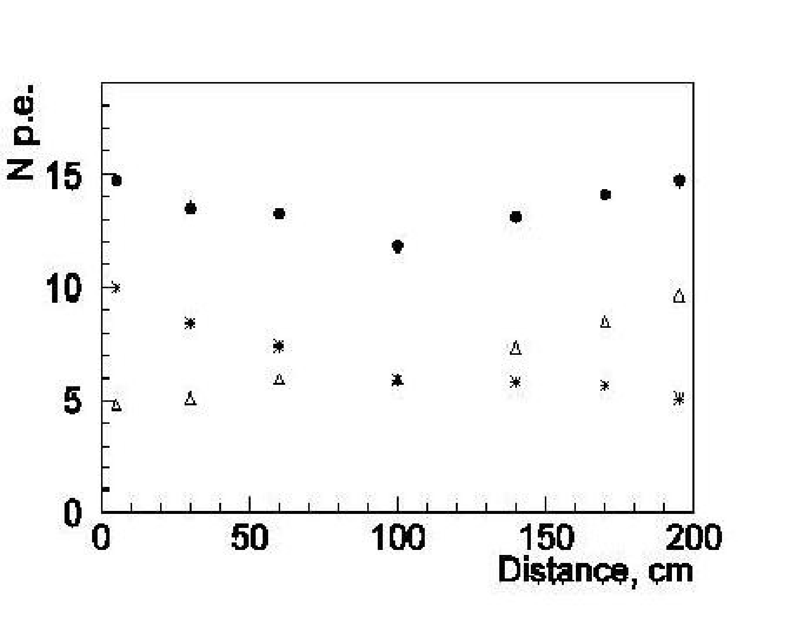
Vertical deformation of central wheel

3D calculation M.Harz

Muon System/Tail Catcher Sensitive Elements Technology



Sensitive Element



Number of Photons detected by SiPM

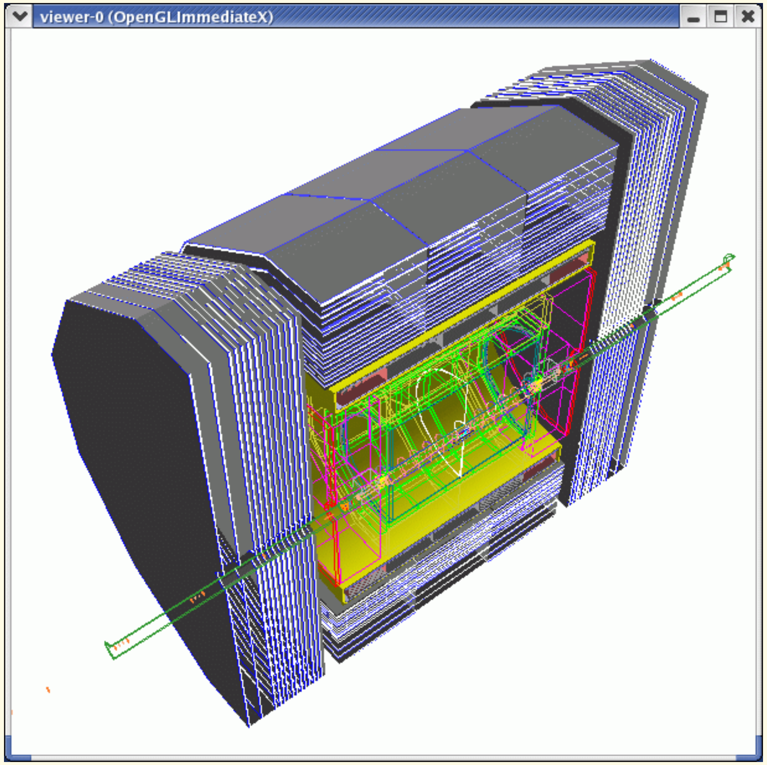
Main Technology Options is Scintillator Strips/Wavelength Fiber with SiPM Readout: 10 mm thickness, 25-30 mm width. 1 mm Wavelength Fiber in the Extruded Groove in the center of the Scintillation Strip. Readout from both side of scintillator strip by SiPM

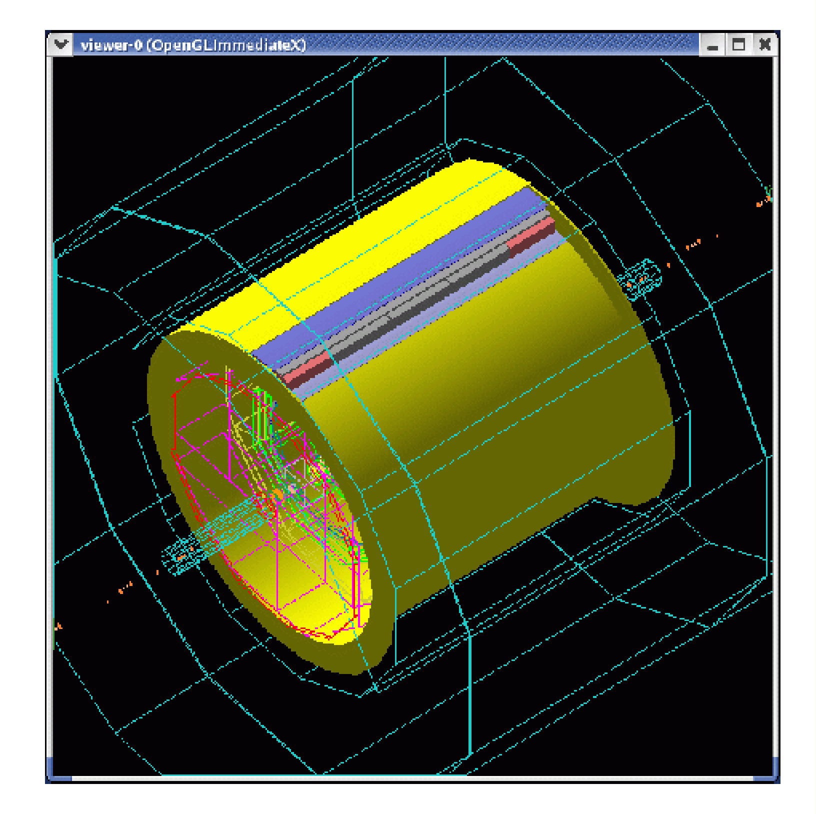
As options is considering the RPC (Resistive Plate Chambers)

Fermi-NICADD Extruder

Technology Facility in Fermilab for production of extruded scintillator/WLS strips
ITEP has similar Facility

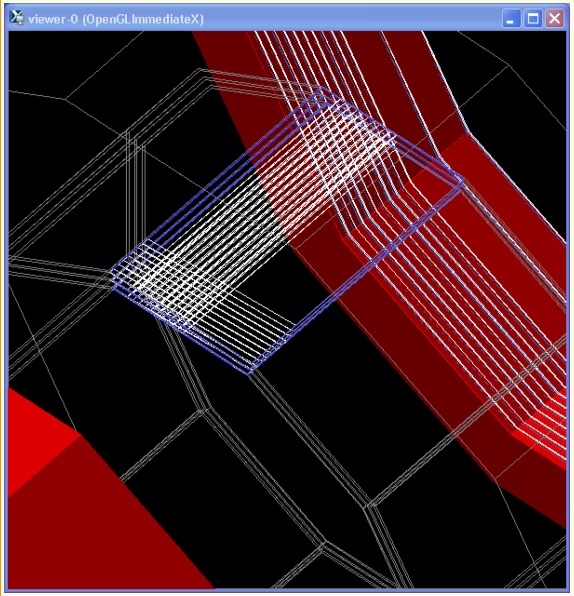
ILD Muon/Tail Catcher System Model

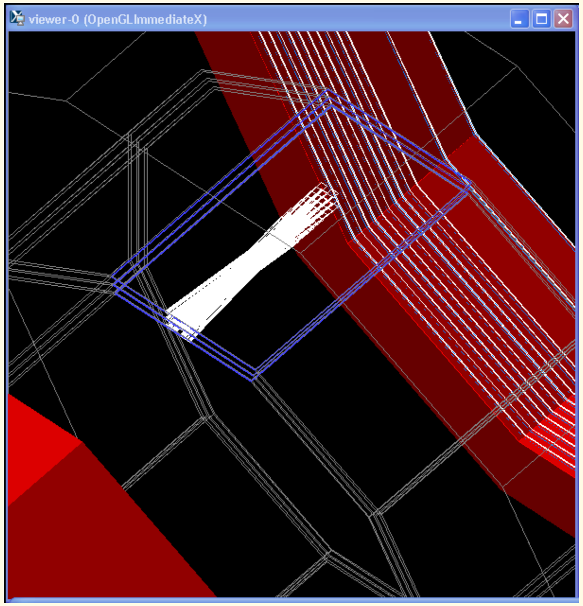


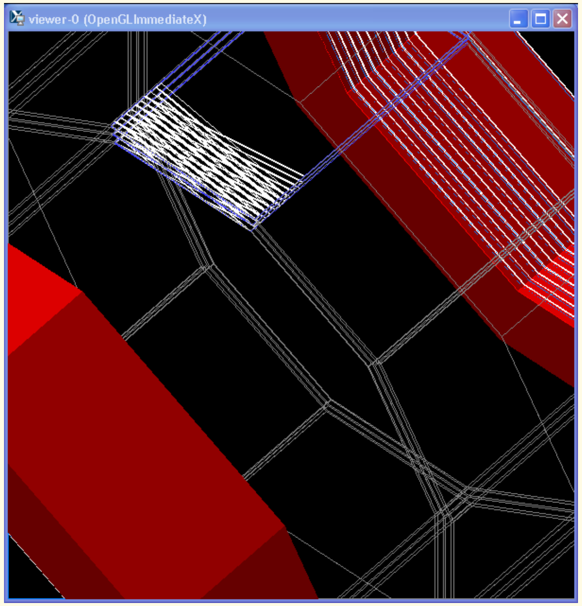


Yoke, Cryostat and Muon System of the ILD detector as described in MOKKA

Detail Simulation of Muon System/Tail Catcher

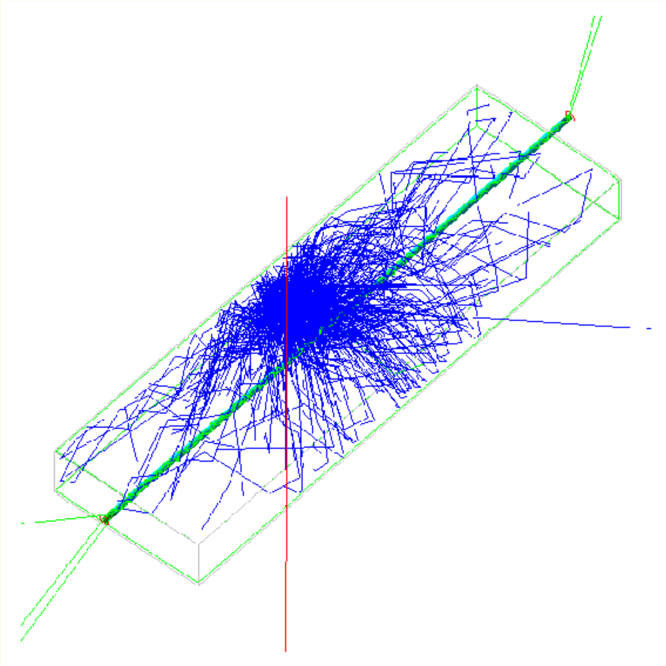


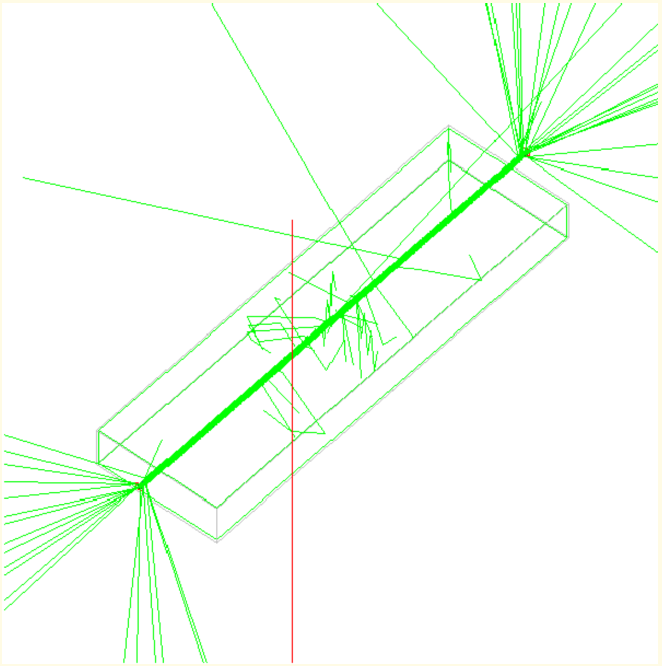




Detail model of the ILD Muon System/Tail Catcher in ILD Framework

Sensitive Elements of ILD Muon System/Tail Catcher





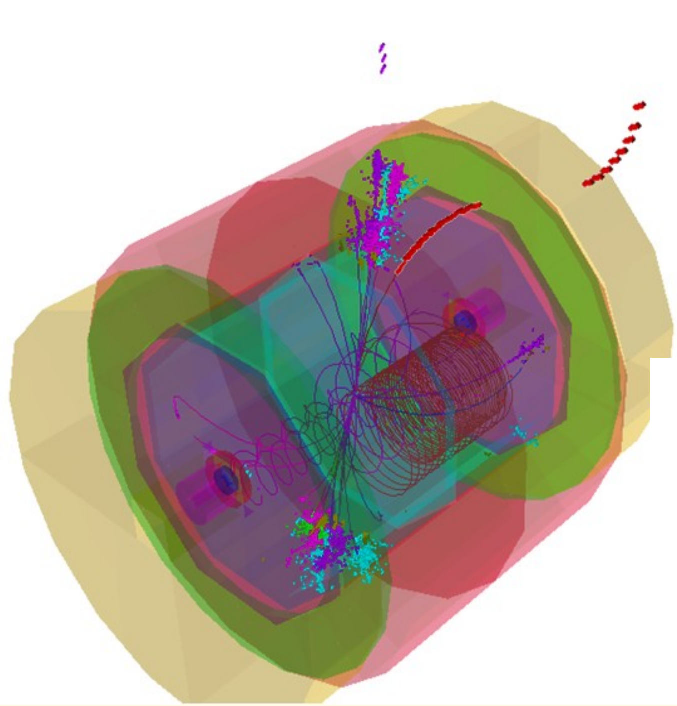
Detail model of the Muon Detector/Tail Catcher Sens Elements:
Full simulation of the Light Propagation and Detection by SiPM

Pandora PFA: Fast Muon Id Function

- The fast muon identification is cut-based and looks for an inner detector track, followed by consistent, minimal energy deposition throughout the calorimeters and muon yoke. It targets muons with energy greater than 2.5GeV

Cuts are placed on:

- The number of occupied layers in each of the ECAL, HCAL and YOKE regions.
- The energy deposited in the ECAL and HCAL regions. Energies are direction-corrected and cuts are linear functions of associated track energy.
- The RMS values for straight-line fits in the ECAL, HCAL and YOKE regions.
- The fraction of mip-like hits in the ECAL and HCAL regions.
- The number of muon yoke hits

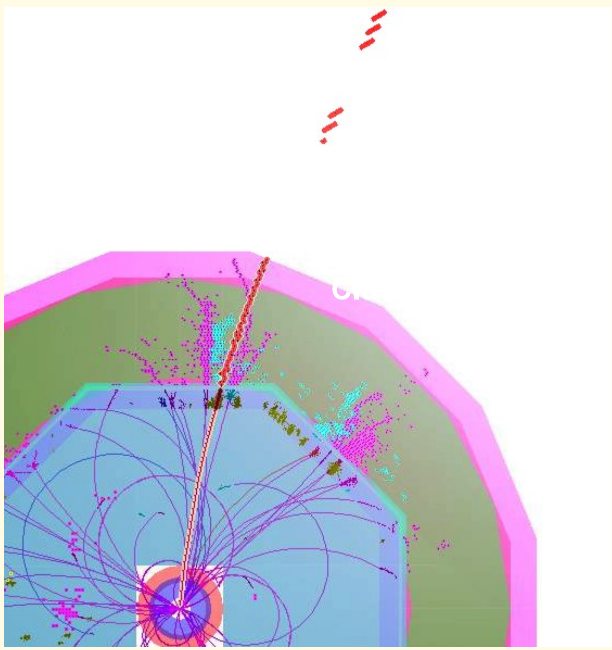


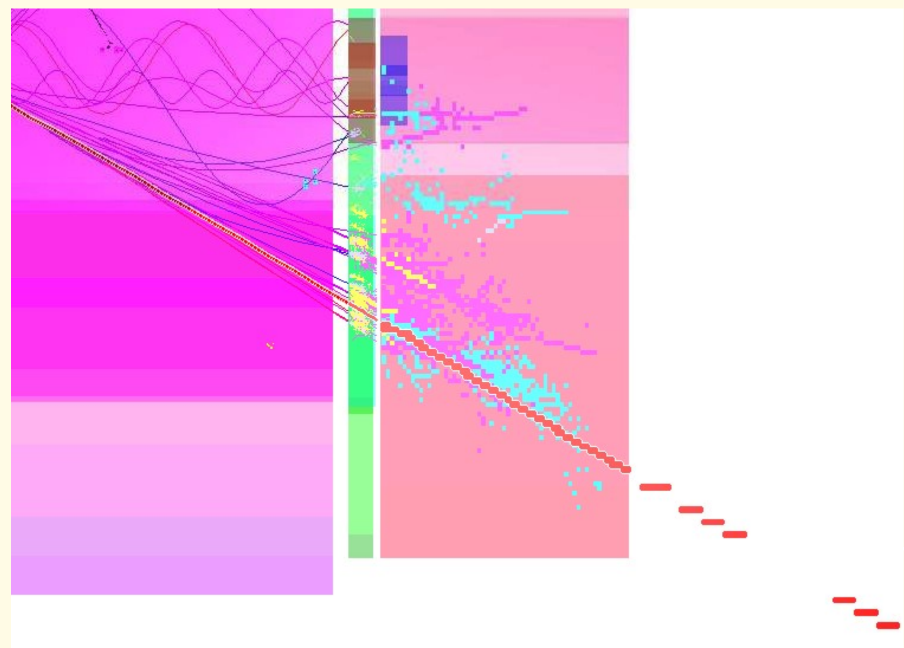
5GeV muon in Z->uds event

Pandora PFA: J. Marshall

Pandora PFA: Muon Reconstruction Algorithm

1. Yoke track candidates are identified using an instance of the Pandora cone-based clustering algorithm, configured appropriately for the coarse instrumentation in this region. Clusters crossing all yoke layers, whilst containing a minimal number of hits are selected.





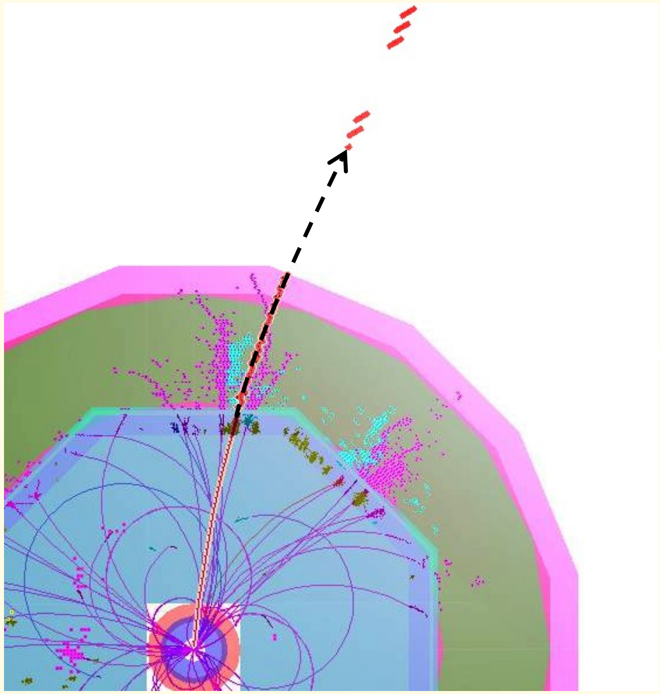
Pandora PFA: J. Marshall

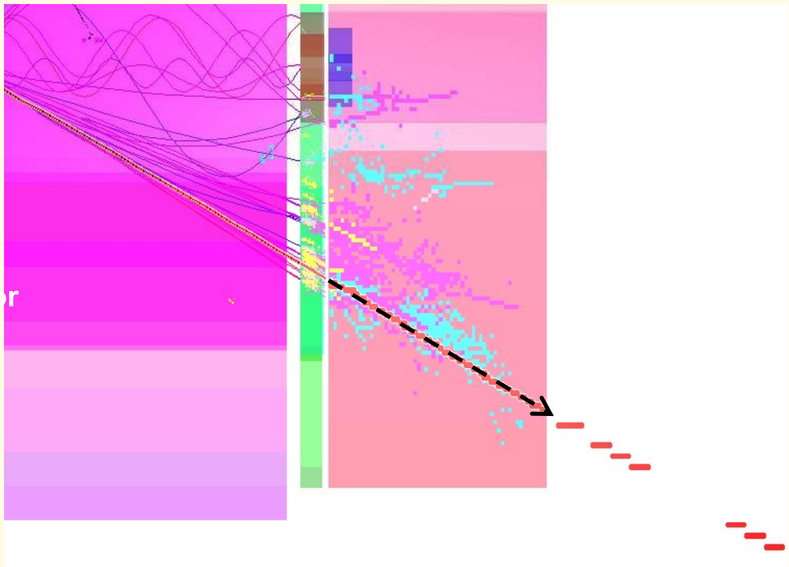
Pandora PFA: Muon Reconstruction Algorithm

2. For each inner detector track above 7GeV, a helix fit to the track is extrapolated to the position of each yoke cluster. This extrapolation accounts for changes in the B-field upon crossing the coil.

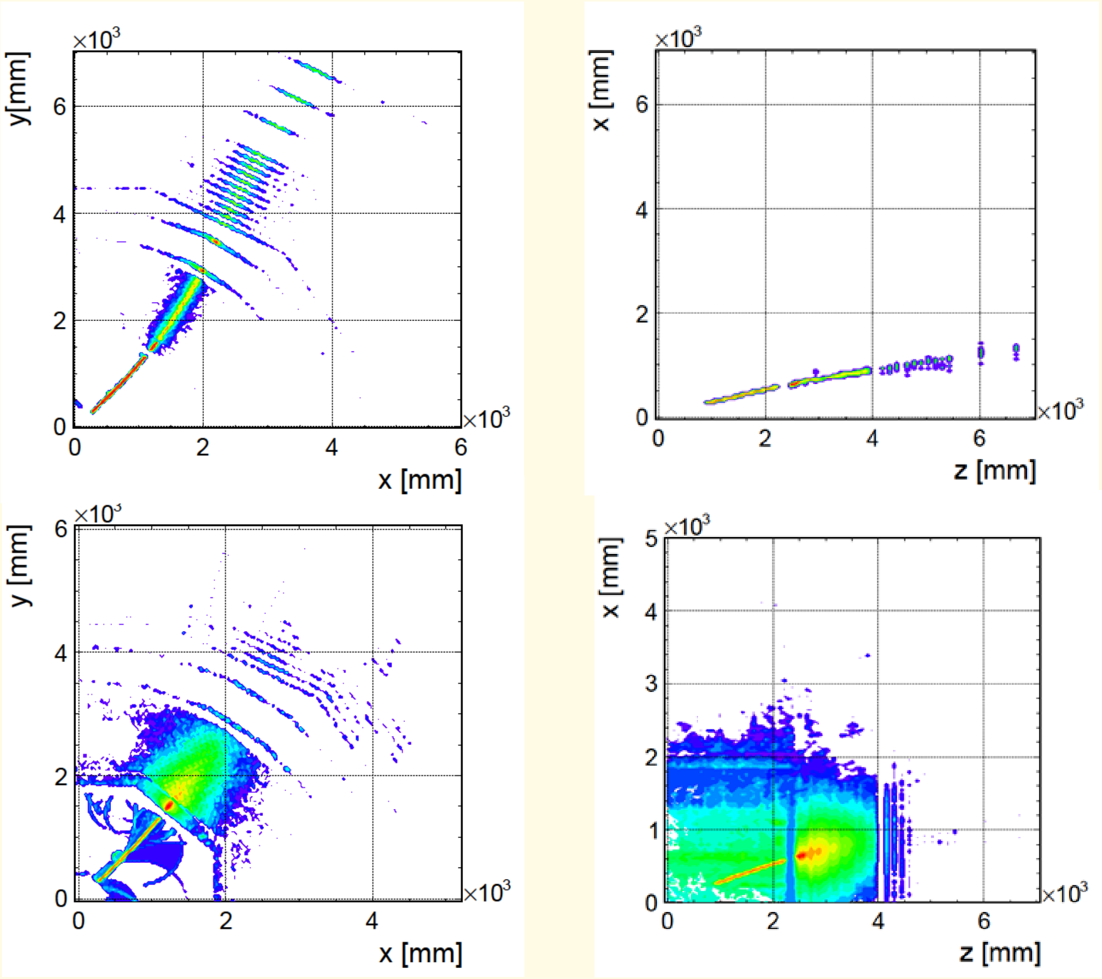
   The helix extrapolation is used to calculate the distance of closest approach to the yoke cluster and also the angle between the helix direction and a linear fit to the cluster.

   Track candidates with opening angles greater than 0.2rad, or distances greater than 200mm are excluded. The closest track is selected and used to calculate the muon properties



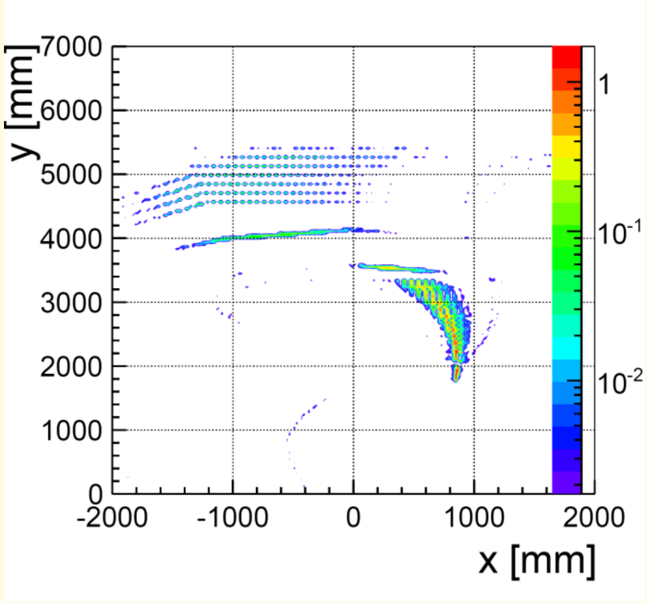


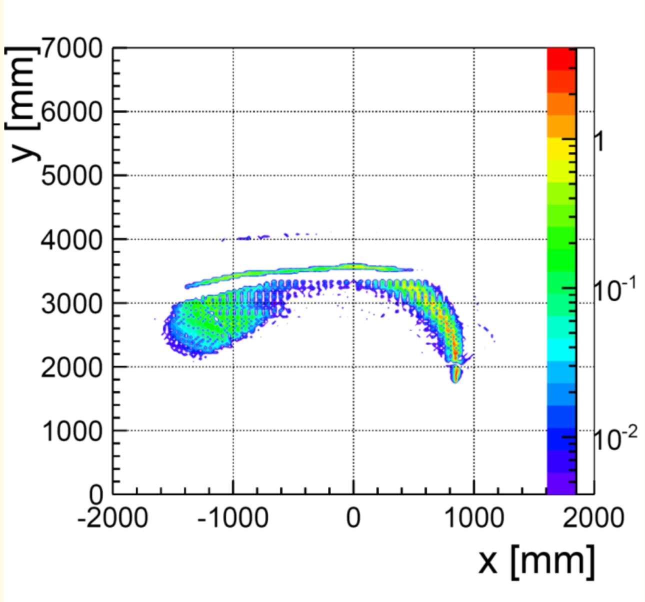
ILD Muon System Performance



Single muons and pions, energy 10 GeV in the Barrel and EndCap

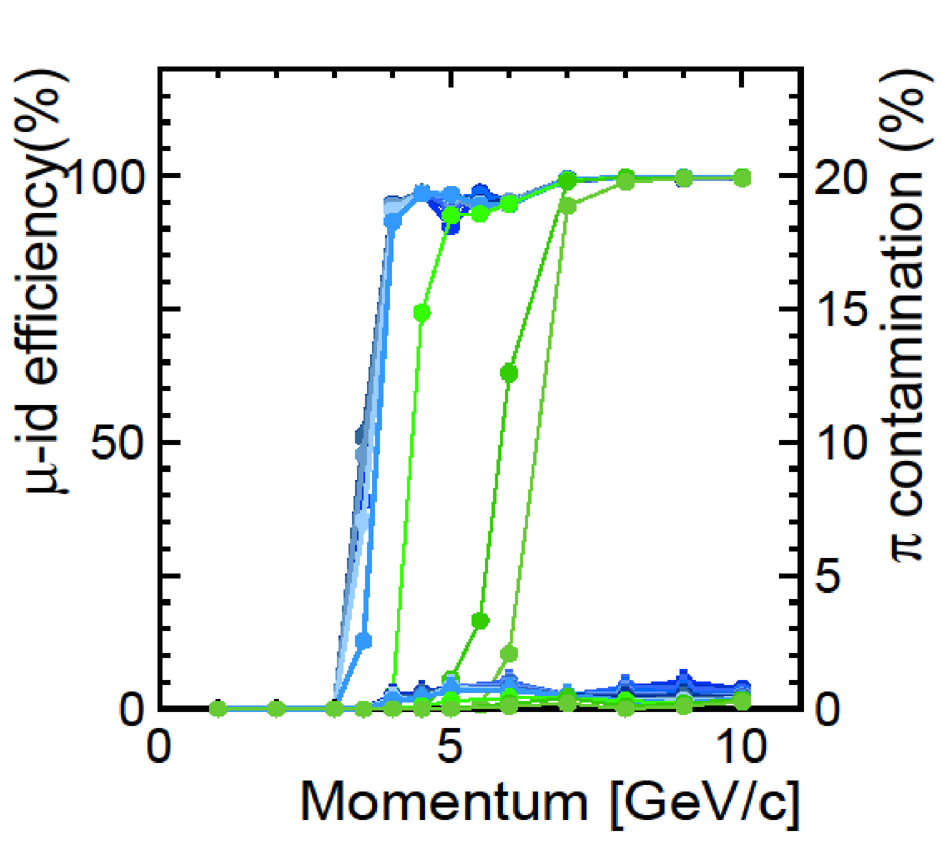
Problem with Low Momentum





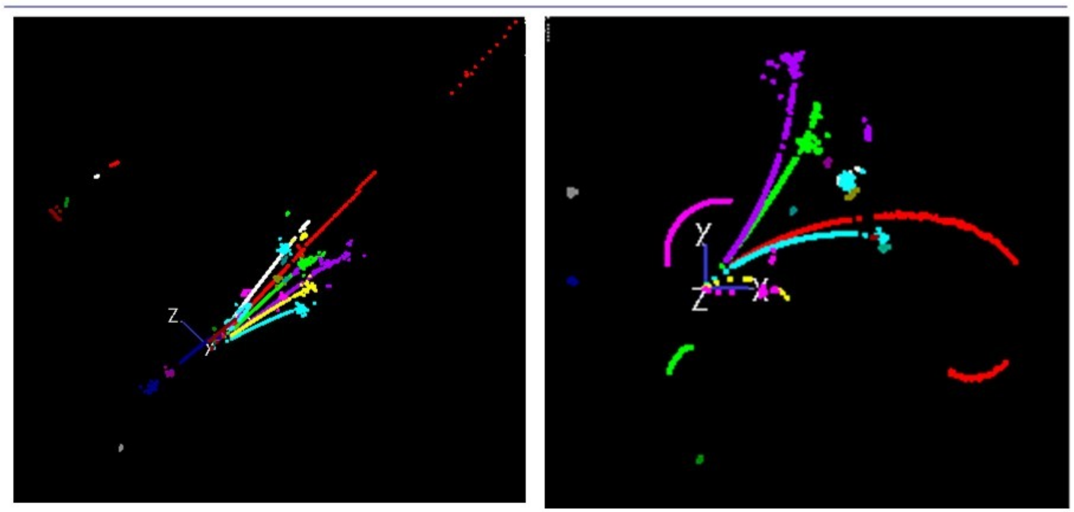
Muons, energy 3 GeV in Barrel, changes the trajectories and lost in non sensitive area of Coil

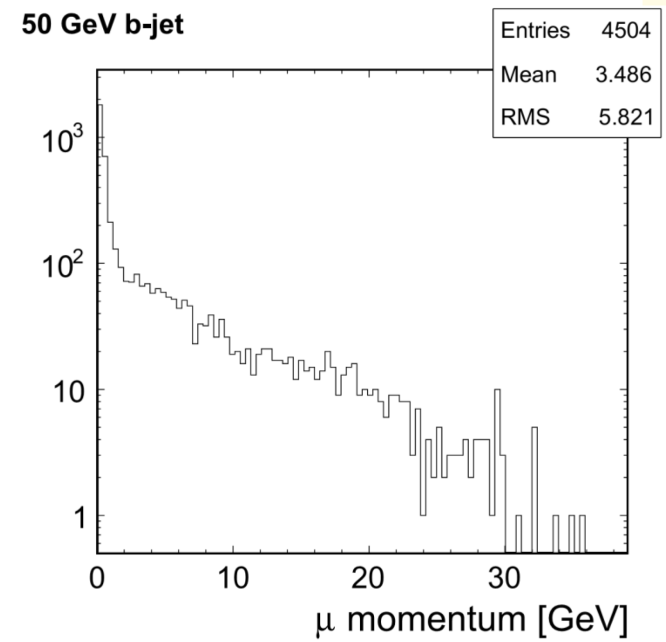
Muon System Identification Performance



Barrel: Muon Efficiency and pion Contamination as function of energy of single particles
Color of the line is correspond to the layers of the Muon System which are used for identification

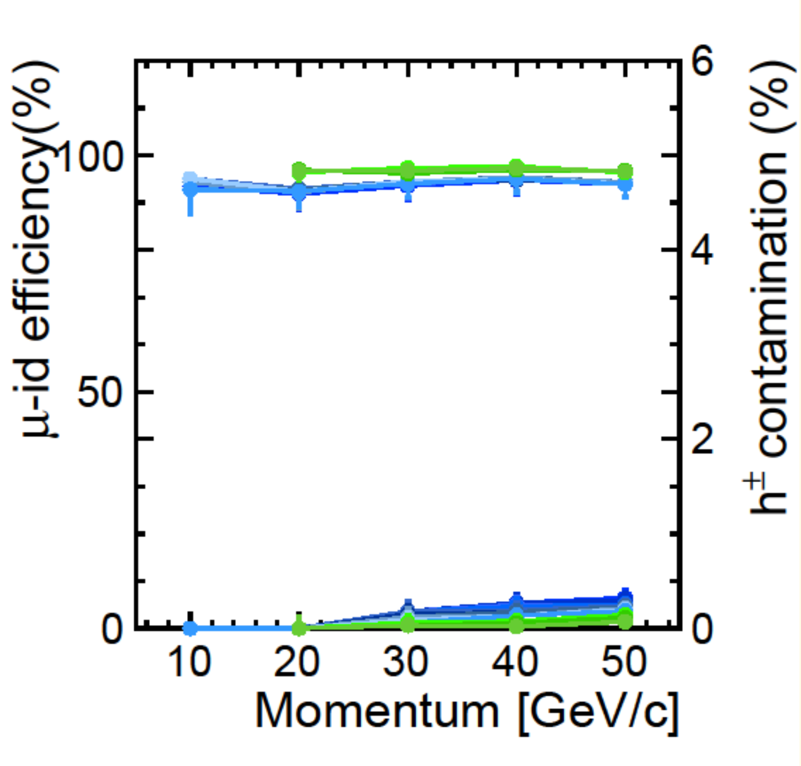
Muon Identification Performance with b-jet





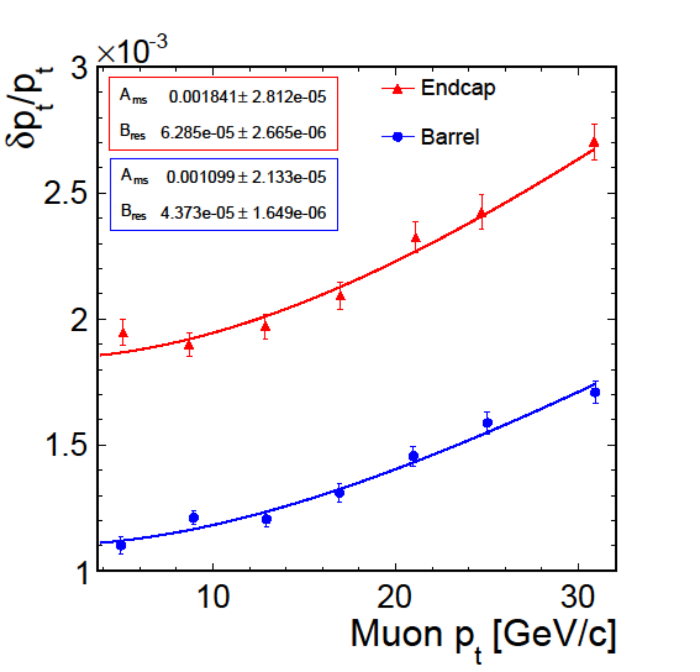
50 GeV b-jet in the ILD , PFA reconstruction (red tracks are muons tracks)

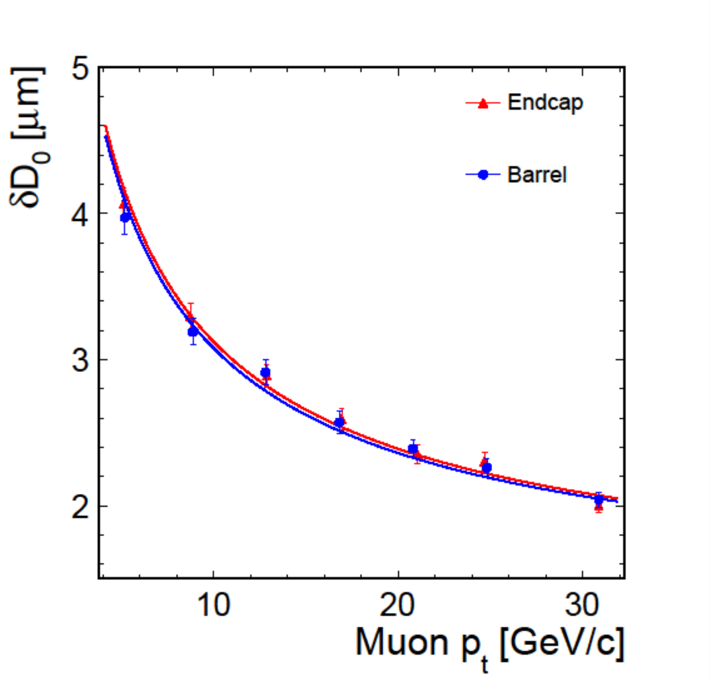
Muon System Identification Performance



Barrel: Muon Identification Efficiency and pion Contaminations in b-jet as function of energy of b-jet (normalised on the energy of muons in b-jets)
Color of the line is correspond to the layers of the Muon System which are used for identification

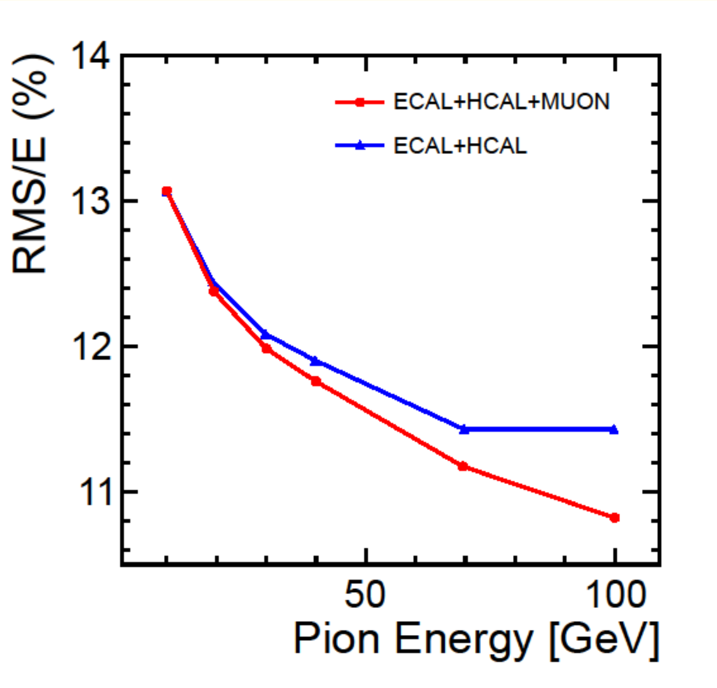
Muon System Reconstruction Performance

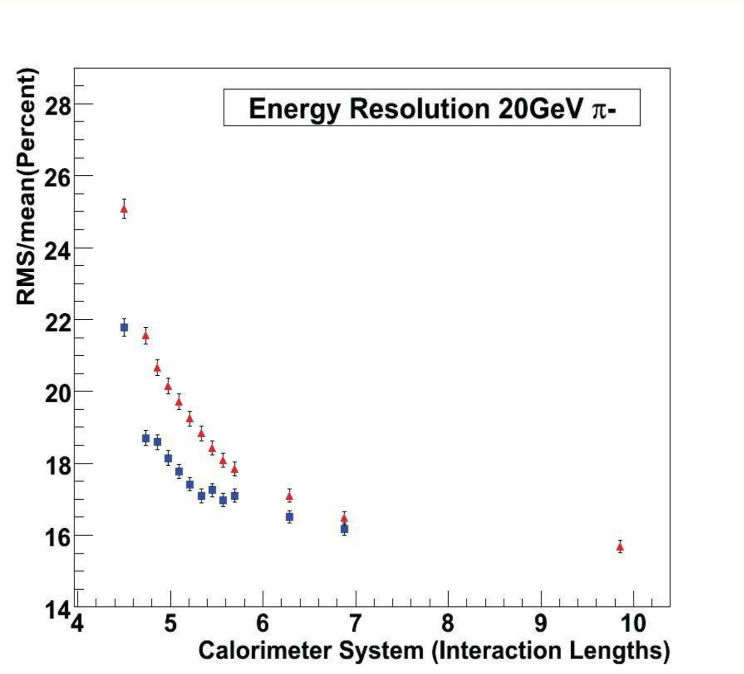




Single particle reconstruction with PFA:
Momentum Resolution and Impact Parameters

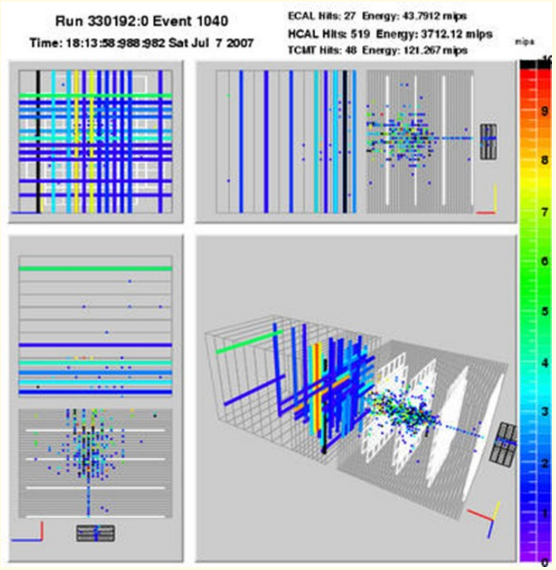
Muon System as Tail Catcher Performance

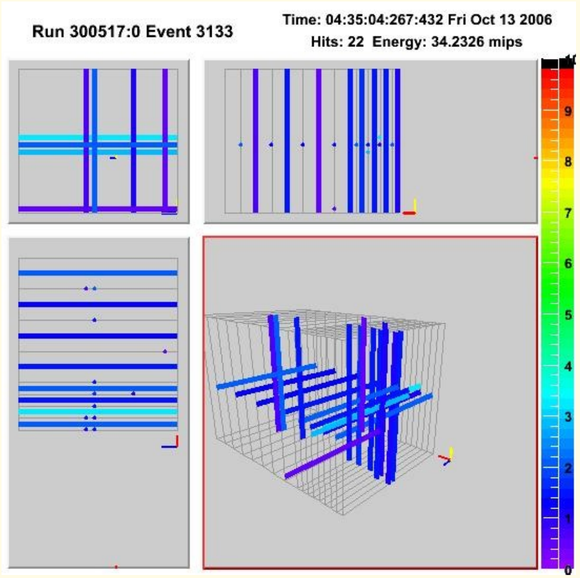




Estimation of the Resolution without and with Tail Catcher
Comparison of Energy Resolution of a Calorimeter System with simulated coil in front of Tail Catcher as a function of the Calorimeter Length (CALICE Study)

Experimental Study of Muon System/Tail Catcher





Test Setup of CALICE including Tail Catcher

Conclusions and Outlook

Muon System:

Muon identification

- ~97% muon identification efficiency and correspondingly about 99% pions rejection at energy >4 GeV
- Muons identification with energies < 4GeV. Needs dedicated analysis

Muon Reconstruction in the ILD detector, using PFA:

- $d(1/pt) = 2.3\ 10^{-5}\ GeV^{-1}$
- $d(D_0) = 2.5$ mm

Conclusions and Outlook

Tail Catcher:

- Improves energy resolution. In particular at high energies
- Full thickness of yoke important for pion rejection (Also needed for achieving low stray field)
- Instrumentation of outer (thick) layers is useful for pion rejection. Much better than just one muon chamber layer on the very outside.

In addition, one very thick instead of three outer iron layers (each about 100tons) would be much more difficult to deal with (manufacturing, transportation and assembly)

- Increasing iron plate thickness from 10 to 20cm probably fine at low energies (low statistics so far), but significant degradation at high energies

Coil Instrumentation:

- Small improvement of energy resolution
- Might be useful for low energy muons identification